8 Light and Shadow: the exploration of sustainable design in the Fiat Lux! project

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Abstract

Light, whether natural or artificial, is essential for illuminating spaces and the activities carried out within them. It enables the perception of three-dimensionality and evokes sensations in humans through its intensity and temperature. Simultaneously, light is inseparable from shadow, which allows for the creation of contrasts, enhances the perception of forms and spaces, and can add dramatic, grotesque, or poetic effects to them.

From the discovery of fire in prehistoric times to the invention of the first practical and efficient incandescent lamp by Thomas Edison in 1879, artificial lighting has always been crucial. It serves purposes ranging from human defence and security to socialization, comfort, and visibility within spaces, enabling the execution of tasks that were previously achievable only during daylight hours.

This article addresses the process of creating and developing the *'Fiat Lux!'* project, while considering the optimization of material and productive resources based on fundamental sustainability principles. The methodology adopted combines problem-based learning with learning by doing experience.

The achieved results materialize the project's initial goals and have allowed first-year Product Design students from Polytechnic Institute of Viana do Castelo to stimulate their imagination, creativity, and critical thinking. They explore the structural potential of flexible and semi-flexible materials, primarily cellulose-based materials.

Keywords: product design, lighting artifacts, sustainable design, fragility and structure.

1. Introduction

The origin of the expression *'Fiat Lux'*, in Latin, can be found in the Book of Genesis of the Christian Bible. One of the most well-known passages describes the seven days of the creation of the universe and all the things and beings that inhabit it, with the expression appearing in the narration of what was created on the first day, "And God said, Let there be light: and there was light."[1] (Genesis 1:3). The equivalent of this expression in Hebrew is also found in the Book of Genesis of the Jewish Torah, similarly separating light from darkness.

In a broader sense, the expression *'Fiat Lux'* refers not only to creation but also to illumination and knowledge, or enlightenment through knowledge, conveying the notion of gaining clarity, enlightenment, or understanding about little-known or unknown subjects.

[1] In the original, in Latin: "*Et dixit Deus: Fiat lux; et facta est lux.*".

The theme of the project presented in this article, *'Fiat Lux!'*, developed within the scope of Introduction to Project 2 course, by students from one of the 1st-year classes of the Product Design degree at the Polytechnic Institute of Viana do Castelo, during the academic years 2021-22 and 2022-23, relates to both aspects: on one hand, it aims to create a product that seeks to transform fragile materials into an artificial lighting object, for a residential space chosen by the student; and, on the other hand, the acquisition of knowledge related to sustainable product design, both in the use of materials and production processes, using methodologies that allow the exploration of concepts, the definition of ideas, and the validation of proposals.

2. Background

2.1. Design for Sustainability

The increase in household income in the decades after World War II led to the emergence of the sustainability concept, mainly due to the excessive consumption of products and services that originated during this period. The recognition of this scenario led, from the 1960s onwards, to various authors[2] expressing critical opinions regarding the unrestrained exploitation of natural resources and uncontrolled industrialization, with ramifications including climate change resulting from pollution, as well as issues related to social inequality, hunger, and diseases (Boylston, 2009; Margolin, 2015; Woodham, 2016). This context, coupled with socio-economic and oil crises and environmental disasters[3], contributed to increasing awareness that resources are not inexhaustible and popularized the term "green" in the 1970s.

From the knowledge and debate on environmental issues, consumer ethics, and human rights, among other subjects related to these themes, emerged in 1987 the coining of the concept of sustainable development. This was formally defined in the report "Our Common Future"

[2] Critical opinions from authors such as:
Vance Packard (1960). "*The Waste Makers: a startling revelation of planned obsolescence*"
Jane Jacobs (1961). "*The Death and Life of Great American Cities*"
Rachel Carson (1962). "*Silent Spring*"
Buckminster Fuller (1969). "*Operating Manual for Spaceship Earth*"
--- (1971). "*Approaching the Benign Environment*"
--- (1972). "*Utopia or Oblivion: The Prospects For Humanity*"
Victor Papanek (1971). "*Design for the Real World: human ecology and social change*"
Gui Bonsiepe (1973). "*Development through Design: working paper for an expert group meeting*"
--- (1973). "*Industrial design: basic guidelines for a policy of UNIDO*"
Fritz Schumacher (1973). "*Small is Beautiful: a study of economics as if people mattered*"
Peter Harper e Geoffrey Boyle (1973). "*Radical Technology: Food, Shelter, Tools, Materials, Energy, Communication, Autonomy, Community*"

[3] 1973 and 1979 – Oil crises in the Middle East
1976 – Seveso, Italy: leakage from storage tanks of the ICMESA chemical industry
1986 – Chernobyl, Ukrainian SSR, Soviet Union: explosion of a nuclear reactor
1989 – Exxon Valdez, Alaska, USA: crude oil spill in the sea

produced by the World Commission on Environment and Development (WCED), widely known as the Brundtland Commission, a commission affiliated with the United Nations (UN).

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (UNWCED, 1987, p.41)

The maturation of knowledge on these topics promoted the implementation of Green Design[4] during the 1980s, which evolved into Ecodesign[5], also known as Design for the Life Cycle, in the 1990s. After the definition of the sustainability tripod, outlined in 1994 by John Elkington, the concept of Ecodesign progressed, becoming a more comprehensive and complex process than before, referred to as Sustainable Design[6].

Despite the concept of sustainability being ancient and dating back to the dawn of humanity, it is expected that its widespread adoption over time will lead to its gradual integration and natural dissemination, moving away from being just a buzzword and assuming its true meaning. In other words, it should be considered intrinsically in the project but treated with little emphasis and without explicit mention (Pakhalé, 2007).

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[4] According to Vieira (2018, p.80), "Green Design aims to incorporate environmental attributes as design objectives, not as constraints, without compromising performance, quality, functionality, and the product's lifespan.

In essence, Green Design values materials through their reuse or recycling but without a life cycle perspective. By resorting to low technology in the production of artifacts, the products ended up being perceived as lower quality, leading to misconceptions in the perception of environmental impact."

[5] Vieira (2018, p.80) states that "One of the various definitions of Ecodesign was formulated in Directive 2005/32/EC (p. 35), according to which Ecodesign 'integrates environmental criteria into the product development phase, with the aim of reducing the environmental impact throughout its life cycle.'

Considering the relationship between raw material extraction, design, production, consumption, and final disposal, Ecodesign encompasses all phases of the product life cycle, where its environmental impact is analyzed. Knowing and understanding the scope of this entire system is vital for design because it is estimated that over 80% of the environmental impact of a product is determined during the project's development (CECIMO, 2012; McNamara, 2009)."

Directive 2005/32/EC of July 6, 2005, regarding the establishment of a framework for setting the eco-design requirements for energy-consuming products. Official Journal of the European Union L 191, dated July 22, 2005. Available from http://eur-lex.europa.eu/legal-content/PT/TXT/PDF/?uri=CELEX:32005L0032&from=EN

CECIMO (2012). *The Ecodesign Directive*. CECIMO - European Association of the Machine Tool Industries. from http://www.cecimo.eu/site/ecodesign-and-self-regulatory-initiative/ecodesign-directive/

McNamara, C. (2009). Systems Thinking. In W. Jedlička (Ed.), *Packaging Sustainability: Tools, Systems and Strategies for Innovative Package Design* (pp. 113-221). New Jersey: John Wiley & Sons.

[6] Vieira (2018, p.81) indicates that "Sustainable Design is a more comprehensive and complex process than Ecodesign, proposing the balanced integration of social and ethical aspects in the product life cycle, along with environmental and economic considerations that characterize the sustainability tripod (Dewulf, 2013).

In this context, 'Design for Sustainability can be recognized as a kind of strategic design' (Manzini & Vezzoli, 2005, p.23) that some organizations have imposed on themselves to achieve environmental sustainability, also considering social equity and, evidently, economic viability.

Moreover, Life Cycle Design and Sustainable Design are completely interconnected in the development of sustainable products and services: the Life Cycle Design methodology underpins Sustainable Design, and the strategic nature of the latter enables the creation of new products (Manzini & Vezzoli, 2005)."

Dewulf, K. (2013). Sustainable Product Innovation: the importance of the front-end stage in the innovation process. In D. Coelho (Ed.), *Advances in Industrial Design Engineering* (pp. 139-166). Rijeka: InTech.

Manzini, E., & Vezzoli, C. (2005). *O Desenvolvimento de Produtos Sustentáveis: os requisitos ambientais dos produtos industriais*. São Paulo: Edusp.

2.2. Product Design and the Sustainable Development Goals (SDGs)

Product design, due to its direct influence on consumption, production, and resource use, and, consequently, on people's quality of life, can play a crucial role in achieving the Sustainable Development Goals defined by the United Nations.

Considering sustainable design as a holistic approach that aims to create environmentally responsible, socially equitable, and economically viable products, systems, and processes in the long term, the pertinence and relevance of its strategic nature to enable the creation of new products (Manzini & Vezzoli, 2005) become evident. These products should be designed to be fully biodegradable or recyclable, thus reintroduced into a production cycle, eliminating the concept of waste (McDonough & Braungart, 2013).

In the context of the development of the *'Fiat Lux!'* project, sustainable materials or the reuse of materials were exploited for the production of lighting artifacts. This approach resulted in products that are moderately durable (considering the materials used) but are resource-efficient and have a low environmental impact. To achieve this, eco-friendly materials were chosen, and/or waste reduction in production was implemented, along with considering the environmental impacts throughout the product life cycle (SDG 12 - Responsible Consumption and Production).

As a result, original and quality products were designed. On one hand, and considering the way the project was approached, it aligns with a quality academic education/training (SDG 4 - Quality Education). On the other hand, it has the potential to stimulate economic growth in the medium term and contribute to the creation of decent jobs (SDG 8 - Decent Work and Economic Growth). What was not considered in the development of this project, due to the short implementation period, was the establishment of partnerships (SDG 17 - Partnerships for Sustainable Development), especially with private sector companies, from which surplus production could have been requested for the execution of prototypes (BCSD, 2022).

However, it is considered, both through the feedback given by participating students and the overall definition of the solutions they found, that the implementation of sustainable and original design projects can contribute to a more equitable, prosperous, and environmentally responsible future.

2.3. Light and shadow in interior spaces

Natural light is essential for the survival of most living beings. For humans, in particular, natural light is crucial for regulating various bodily functions. The continuous change between day and night synchronizes humans with the solar cycle, the so-called circadian rhythm. This rhythm is responsible for regulating the internal biological clock and hormonal regulation, playing a vital role in metabolic, immune, and energy processes, which, in turn, impact cognitive and physical performance. Light also strongly influences psychological aspects, stimulating behavior, mood, and the individual's well-being (Blume, Garbazza & Spitschan, 2019).

Therefore, it is essential to recognize the importance of light in creating atmospheres that promote psychological well-being. In addition to regular exposure to natural light, strategies that provide the appropriate quantity and desired quality of light can contribute to a psychologically healthy environment (Plummer, 2009).

The attention given to this issue aims to meet practical visibility needs and the perception of three-dimensionality. It plays a significant role in shaping spaces, highlighting architectural details and objects, and influencing the overall atmosphere of a place.

Throughout history, lighting has maintained a close relationship not only with architecture but also with various forms of artistic expression. Both light and shadow emerge as vital elements in visual language, providing the opportunity to create, through drawing, painting, photography, and sculpture, effects that expand space, give depth, and highlight volumetrics.

Light and shadow play a crucial role in adding meaning, offering the ability to create effects ranging from dramatic, ironic, grotesque, to poetic. From the realm of visual arts to performing arts, light has been a constant presence in the creative process. In different cultural, historical, social, and religious contexts, light and shadow have been associated with symbolic meanings and specific values, becoming culturally significant elements laden with importance over time (Pallasmaa, 2005).

Given that interior lighting is fundamental for creating environments that promote visual comfort, safeguarding productivity in workspaces and cozy atmospheres in residential spaces, it is essential to know how to control the intensity of the light source, the color temperature emitted, and the direction of its beams. A thorough understanding of the context surrounding this subject enhances the proper development and execution of the design of lighting artifacts. These artifacts, beyond being considered as products that complement the aesthetics of a space, contribute to the creation of lighting that highlights specific areas, enhances volumes, textures,

and colors of surrounding objects, and can even influence the mood and well-being of individuals who work or reside in that location.

3. Projects scope, main problem and objectives

'*Fiat Lux!*' project was designed with the aim of stimulating students' imagination, creativity, and critical thinking, as well as acquiring knowledge and skills in topics related to sustainable design and properties of artificial light that contribute to defining different atmospheres in interior spaces.

The project aimed to transform translucent or opaque materials, obtained as flat surfaces of cellulose origin (paper and cardboard) and/or polymeric origin (polypropylene sheet), into lighting artifacts for a residential space chosen by the student. In assembling the parts, they should preferably use cuts and fits, with the option of using specific adhesive for the material or small accessories (fasteners, rivets, wires, elastics, etc.). Furthermore, if necessary to shape the structure, a rigid material (wood or metal) could be added.

As electrical components, the project should include a socket that best suits the design, an electrical cable with an appropriate length for the type of lighting fixture, a switch, and a male plug (even for ceiling fixtures, for classroom presentation). The color of these components was at the discretion of the student. The LED bulb to be used in the prototype should be chosen according to the desired intensity and color temperature, taking into account the functions associated with the use of the object in the selected space.

In addition to enabling the performance of tasks typically carried out in the space for which it was designed (working/studying, relaxing, cooking, dining, etc.), the final outcome should be easily reproducible, both in a handmade and industrial manner, and possess a contemporary aesthetic appearance.

4. Project methodology

The '*Fiat Lux!*' project spanned 8 weeks with in-person supervision twice a week, totalling 48 hours of contact.

Project-based learning methodology was used in the development of this project, with students actively engaged in applying their knowledge to solve a real-world situation. By placing the project at the core of the process, collaboration and the development of practical skills, related to the learning by doing methodology, were also promoted. Simultaneously, this approach

proves to be relevant and meaningful to the students' journey and interests, both within the academic environment and, in the future, for solving problems, developing products, and improving processes in a professional/business setting.

Considering that the project was developed by first-year Product Design students, due to their limited experience, the first two phases of this methodology (problem definition and task and deadline planning) were presented and discussed with them before they proceeded to the next phase.

The third phase, implementation, was divided into three moments:

1) Preliminary project, which involved researching, collecting, and analysing information about characteristics and properties of artificial light, including propagation properties (reflection, refraction, and absorption), light beam intensity (Lumen), color temperature (Kelvin), defining these parameters for the residential space selected by each student, as well as visual references from similar spaces and products. It also included the research and collection of materials that fit within the sustainability criteria defined for the project. This moment lasted for 1 week.

2) Project, which involved conceptualizing and ideating the product, along with formal and structural development in the form of sketches and study models. This moment lasted for four weeks and was concluded with the final product proposal, presented in the form of technical drawings, and a composition study for the product label.

3) Production, lasting two and a half weeks, during which the final prototype and its label were produced. This phase also included the preparation of a presentation report covering the entire development process of this project, which included, among other elements, justificatory and descriptive product documentation and an assembly manual, if applicable to the product.

The fourth phase, evaluation, took place throughout the previous phase and after the communication of the final project outcome. During the implementation phase, students presented the status of their project development on a weekly basis, encouraging critical analysis and providing feedback. This allowed for error identification and resolution, fostering reflection on the work done up to that point.

In the final phase, which involved communication and presentation of the final result, each student defended their project, showcased and tested their prototype, and self-assessed their

work process. This allowed students to share their findings and acquired knowledge. At this stage, general feedback was also provided on the work done by each student.

5. Projects results

In total, 36 prototypes were produced, 19 in the 2021-22 academic year and 17 in 2022-23. These prototypes can be grouped into two main typologies: one according to the residential space and the activities carried out there, and the other according to the mode of application/utilization of the lamp (Tab. 1).

Tab. 1 - Typology/quantity of prototypes executed by students

TYPOLOGY OF RESIDENTIAL SPACES		LAMPS				
	activity	ceiling	floor	table	wall	total
Bedroom	study	-	-	1	-	1
	relax	-	-	11	-	11
	study + relax	-	-	3	-	3
	nursery room	-	-	1	-	1
Dining room		1	-	-	-	1
Hallway		2	-	5	1	8
Living room	relax	1	1	9	-	11
	total	**4**	**1**	**30**	**1**	**36**

It is understandable and expected that the majority of the projects are table lamps for the bedroom since, considering it is a prototype they could benefit from, most students selected the residential space where they spend most of their time.

The majority of the results are surprising due to their formal diversity, contemporary aesthetic language, and the structural quality of the prototypes. Moreover, they generally align with the objectives set for this project.

It is believed that many of the results have significant potential for industrial production, although some details may still need to be adjusted or revised for mass production.

Fig. 1 – Table lamps designed by Tiago Martins, Sara Neves and Guilherme Sousa (top three projects made with paper and polypropylene sheet). Table lamps designed by Tiago Faria and Inês Alves (bottom two projects made with paper sheet). (2021-22)

Fig. 2 - Table lamps designed by Ana Alves, Mirian Banholzer, Bruna Vaz, Joana Vieira and Isis Pinto. Floor lamp designed by Leonor Veiga. Ceiling lamp designed by Lara Abreu. (all projects made with paper) (2022-23) (from left to right and top to bottom)

6. Conclusion

The exploration of fundamental considerations about sustainable design, as well as characteristics and properties of artificial light, allowed to demonstrate that it is possible to raise

students' awareness of issues, limitations, and solutions related to these topics. This dual approach resulted in a set of original products.

Throughout the '*Fiat Lux!*' project, students delved into some of the complexities of sustainable design by incorporating eco-friendly materials and/or reconsidering the life cycle of less sustainable materials. The final result not only met practical lighting needs but also raised awareness about responsible production that considers the environmental impact both pre and post-consumption.

The intrinsic relationship between light and shadow, explored not only as a functional consequence but as a means of expression that imparts additional dimensions to the space where the lighting artifact is used, highlights the rationality and emotionality upon which each student's project concepts are based. Furthermore, the diversity of luminaire typologies created demonstrates the students' ability to apply creativity and functionality in various contexts.

The project-based learning methodology proved to be an effective approach, allowing students not only to acquire theoretical knowledge but also to actively apply that knowledge in solving a real-world problem. Continuous guidance, feedback, and regular evaluation contributed to the constant refinement of the projects.

In the end, the '*Fiat Lux!*' project is not just a set of lighting artifacts but a tangible manifestation of the transformative potential of sustainable design. As these eco-friendly and original products stand out, not only for their contemporary aesthetics but for the awareness narrative they embody, they point towards a future where sustainability is not just a choice but an intrinsic essence of design.

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